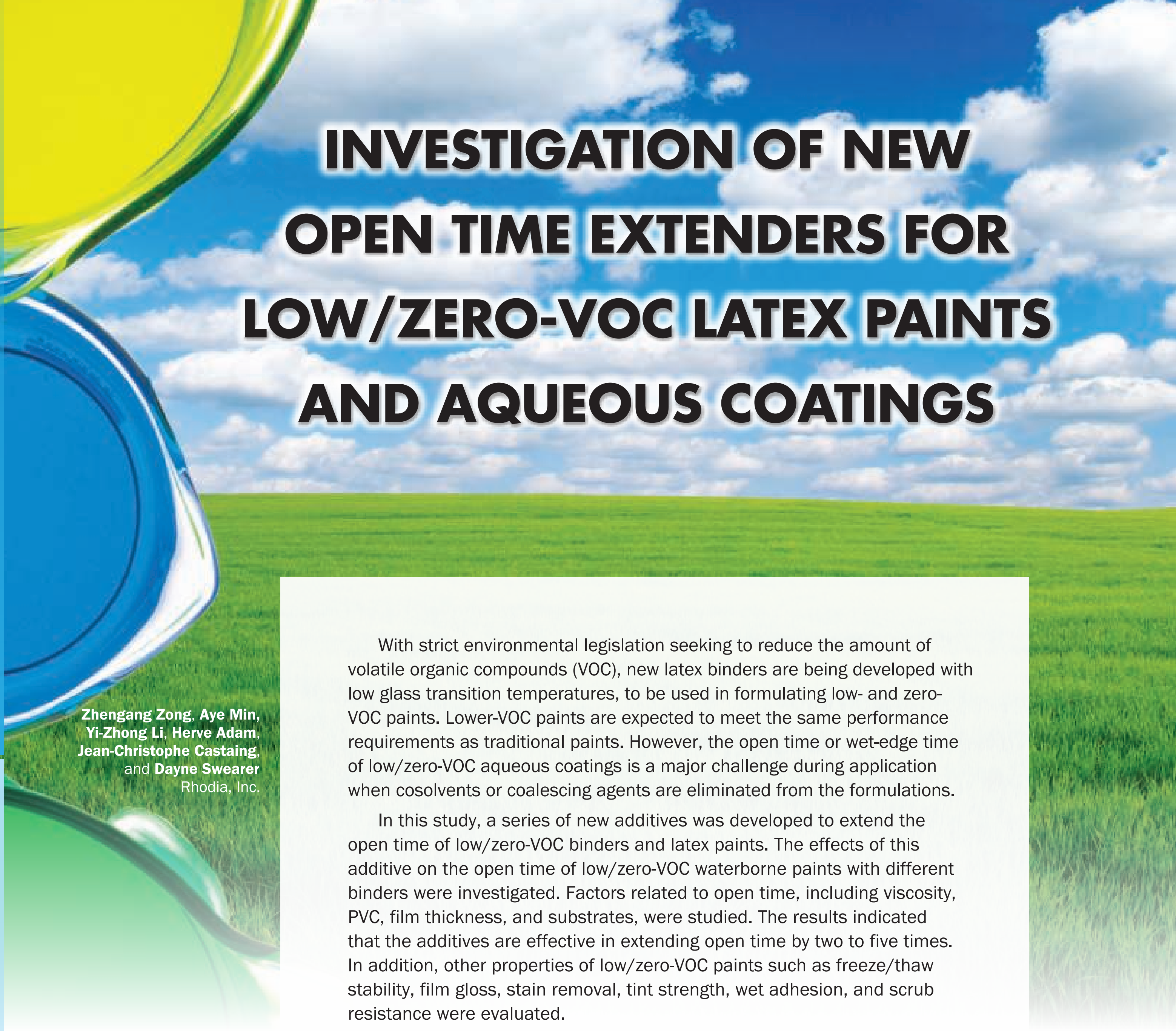

INVESTIGATION OF NEW OPEN TIME EXTENDERS FOR LOW/ZERO-VOC LATEX PAINTS AND AQUEOUS COATINGS

Zhengang Zong, **Aye Min**,
Yi-Zhong Li, **Herve Adam**,
Jean-Christophe Castaing,
and **Dayne Swearer**
Rhodia, Inc.

With strict environmental legislation seeking to reduce the amount of volatile organic compounds (VOC), new latex binders are being developed with low glass transition temperatures, to be used in formulating low- and zero-VOC paints. Lower-VOC paints are expected to meet the same performance requirements as traditional paints. However, the open time or wet-edge time of low/zero-VOC aqueous coatings is a major challenge during application when cosolvents or coalescing agents are eliminated from the formulations.

In this study, a series of new additives was developed to extend the open time of low/zero-VOC binders and latex paints. The effects of this additive on the open time of low/zero-VOC waterborne paints with different binders were investigated. Factors related to open time, including viscosity, PVC, film thickness, and substrates, were studied. The results indicated that the additives are effective in extending open time by two to five times. In addition, other properties of low/zero-VOC paints such as freeze/thaw stability, film gloss, stain removal, tint strength, wet adhesion, and scrub resistance were evaluated.

Various techniques have been employed to characterize open time and wet-edge time. A new method was developed to characterize open time/wet-edge time and the film formation process. Correlations among film formation, physical properties, and coating performances are discussed.

INTRODUCTION

The open time of paints and coatings is the period of time during which the wet paint remains workable after it has been applied to a substrate, allowing for corrections, like rebrushing or rolling, to be made without resulting in any surface defects. Wet-edge time refers to the time when a painter applies fresh paint to a wet painted area and the fresh paint can merge in without causing any visible lap in the dried coating films.

For traditional waterborne coatings and paints, glycol or glycol ethers are added to paint formulas to increase the open time or wet-edge time, and these solvents allow latex particles to move freely when all or most of the water has evaporated from the aqueous paint system. The glycol used in latex formulations can also stabilize latex particles against coagulation during freezing and thawing. The effects of ethylene and propylene glycols on the drying process of latex paints were investigated by Andrews.[1] His work showed that the glycols can improve freeze/thaw stability; aid in the coalescence of latex particles; and increase open time or wet-edge time because the glycols are water-soluble, and they reduce the vapor pressure of water and lower the freezing point of aqueous solutions. Sperry et al.[2] reported using low levels of surface-active agents to reduce the evaporation rate of water from waterborne polymers. The use of low concentrations of long-chain aliphatic suppressants in aqueous coatings increased the open time or wet-edge time of the coating and improved the film formation and adhesion. This addition method of surface-active evaporation-suppressing agents to aqueous coatings could generate a hydrophobic monolayer at the air–water interface and can prevent water evaporation from aqueous systems. Adamson et al.[3] discussed a method for extending the open time of aqueous coatings employing complementary reactable groups in the latex polymer and modifying compounds which provide ionic or covalent binding. The method of incorporating hydrophilic moieties into or onto latex particles of waterborne paints and coatings can keep water molecules between the latex particles. The resulting interactions between a hydrophilic moiety and water can retain the water for a longer period of time. Farwaha et al.[4] disclosed a latex composition which incorporated polymerizable saccharide monomers and the latex coatings exhibited improved open time. Buckmann and co-workers from DSM[5] patented an aqueous coating composition comprised of crosslinkable water-dispersible oligomers, a dispersed polymer, and, optionally, non-crosslinkable water-dispersible oligomers. The aqueous coatings improved open time and wet-edge time. Akkerman et al. from Nuplex Resins[6] reported on a hybrid resin with a hydrophobic core and hydrophilic shell used to improve the open time of waterborne coatings. The special morphology resulted in good open time properties. Overbeek et al.[7] discussed their work on extended open time using very low viscosity oligomers and a high Mw dispersed polymer. The very low viscosity oligomers remained in a liquid state, even when the water evaporated from the aqueous coating. Recently, Meng[8] investigated the application of fluorosurfactants on open time of low-VOC coatings. McCreight et al.[9,10] presented their work on new additives to extend open time and wet-edge time of aqueous coatings.

Even though many attempts have been made to improve the open time of waterborne paints, and a number of test methods to determine open time have been developed over the past 30 years, improvements in open time and wet-edge time of waterborne low/zero paints are very limited.

In this study, a new additive—Rhodoline OTE—was developed to extend open time of low/zero-VOC binders and latex paints. The effects of the additive on the open time of low/zero-VOC waterborne paints with different binders were investigated. The results indicated that Rhodoline OTE (referred to here as “Additive 1”) is an effective additive to extend open time by two to four times. Various parameters of open time, including viscosity, PVC, film thickness, and substrates, have been studied. In addition to the open time, other properties such as freeze/thaw stability, film gloss, stain removal, tint strength, wet adhesion, and scrub resistance were evaluated.

A new method was developed to characterize open time/wet-edge time and the film formation process. Correlations among film formation, physical properties, and coating performances are discussed.

EXPERIMENTAL

Materials

Acronal Optive 130, used in this study, is a commercial latex binder from BASF which was developed for low/zero-VOC architectural paints. AMP-95 (2-amino-2-methyl-1- propanol) (Dow Chemical, ANGUS); Tiona 595 titanium dioxide; Aquaflow NHS 310; and Acrysol SCT-275 were obtained from their respective manufacturers. Rhodoline OTE 500, Rhodoline OTE 400, Rhodoline 286 N, Rhodoline 643, and Antarox BL-225 are all commercially available products from Rhodia.

Low/zero-VOC paints are commercially available products. The VOC values and binders are shown in *Table* 1.

Substrates

Various substrates were used to determine open time and wet-edge time on different surfaces, including a Leneta chart, glass panels, a cedar panel, and drywall.

Instruments

The gloss reading of the coating film was performed using a BYK-Gardner Micro-TRI-Gloss glossmeter. A low shear viscosity, Krebs unit (KU), was measured on a Stormer viscometer (Brookfield), and a high shear viscosity, ICI, was obtained using an ICI cone and plate viscometer (Research Equipment (London) Ltd.). Scrub resistance and stain resistance were measured on a Gardco Scrub Tester (Paul N. Gardner Company). The open time of the latex binder was measured on a minimum film forming temperature (MFFT) Bar 90 (Rhopoint Instruments Ltd.) and the temperature was controlled from 23–50°C.

Paint Formulations

To minimize batch-to-batch variation, the dispersion was made in a master batch and then split into different portions. The letdown ingredients were added using the order of formulas. The finished paints were equilibrated at

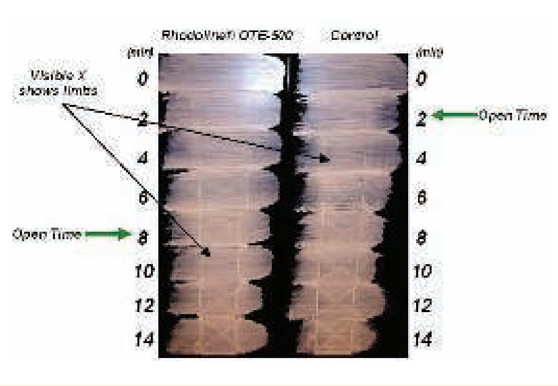

Figure 1—Open time results of a commercial zero-VOC paint with and without Additive 1.

least 24 hr before beginning the evaluation. Additive 1 was formulated into low- and zero-VOC acrylic paints and the formulations in the given zero-VOC formulas contained no coalescent agents or cosolvents.

Paint Evaluation and Properties Measurements

All paint properties were measured according to ASTM standard test methods.

Open Time Measurement: The open time of latex paints was measured according to ASTM test method D7488-10. The open time test was conducted in a constant temperature and humidity room (CTHR), (20°±2°C, 50 ±5%). The tested paints were applied to a Leneta chart using a 10 mil (250 microns) Dow drawdown bar. After casting the paint samples, a mark (X) was made immediately using a pencil eraser. The test paint was then applied in perpendicular sections, brushing each section across the initial painted section with 15 strokes. The perpendicular sections were repeated at two-minute intervals. The test substrate was allowed to dry in the CTHR for 24 hr prior to rating the results. The time at which the X marks became visible was recorded.

Viscosity: The viscosity of the original latex binders and the latex samples after each freeze/thaw cycle were measured by a Brookfield viscometer using #3 spindle at 60 RPM. The Stormer viscosity of formulated latex paints was measured according to ASTM D562, and the higher shear ICI viscosity was measured following ASTM D4287.

Gloss: The paints were drawn down side by side on sealed Leneta charts with a 3 mil bird drawdown bar, and the films were allowed to dry for 24 hr at room temperature. The gloss was measured at several points on the paint films at 20°, 60°, and 85° and the gloss meter and average readings were recorded for each angle.

Freeze/Thaw Stability Testing: The freeze/thaw stability of latex binders and latex paints was measured by ASTM test method D2243-95. The general procedure was, as follows: a half pint of latex or latex paint was kept at −18°C for 17 hr in a freezer. The sample was removed from the freezer and allowed to thaw for more than five hours at room temperature and transferred to a water bath at 25°C for two hours. That represented one freeze/thaw cycle. Before measuring the viscosity, the

Table 1—Effects of Additive 1 on Open Time of Commercial Low/Zero-VOC Paints

Low/Zero-VOC Commercial Paints	VOC (g/L)	Open Time, min Additive 1	Control	Binders	Source
Paint 1	0	8	2	100% Acrylic	U.S.
Paint 2	0	4	0–2	Acrylic/vinyl/styrene acrylic polymer	U.S.
Paint 3	low	6	0–2	100% Acrylic latex, N/A	U.S.
Paint 4	41	4	0–2	Acrylic latex (proprietary)	U.S.
Paint 5	0	10	2	Vinyl acetate/acrylic copolymer	U.S.
Paint 6	0	8	2	Acrylic polymer	U.S.
Paint 7	0	10	2	100% Acrylic (25852-37-3)	U.S.
Paint 8	50	8	2	Acrylic polymer, proprietary	U.S.
Paint 9	50	12	2	Ethylene acetate (25067-01-0), butyl ester polymer	U.S.
Paint 10	50	10	0–2	Vinyl acetate/acrylic copolymer	U.S.
Paint 11	50	4	0–2	Acrylic	U.S.
Paint 12	30	6–8	2	Acrylic	EU
Paint 13	29	4	0–2	Acrylic	EU
Paint 14	28	6	4	Acrylic	EU
Paint 15	29	6–8	0–2	Vinyl acrylic	EU
Paint 16	6	6–8	2	Acrylic	EU
Paint 17	low	10	6	NA	AP
Paint 18	low	10	6	NA	AP
Paint 19	NA	10	2	NA	AP

thawed latex or paint was mixed well with a spatula. The viscosity was measured using a Brookfield and a Stormer viscometer for latex and latex paint, respectively.

Scrub Resistance: Scrub resistance was measured in accordance with ASTM D2486. The wet paints were applied to Leneta black charts at 7 mil and allowed to dry over seven days at room temperature. The coated charts were loaded over a shim on the glass plate in the Gardco scrub tester so that the coating film was perpendicular to the direction of nylon brushes. Standardized scrub media (7 mL, Leneta SC-2) was applied evenly into the brushes and 5 mL water was added to the test panels at the beginning. Before starting the test, it was confirmed that the coating films were centered and the brushes would travel over the shim during a moveable cycle. At every 400 cycles, the scrub process was stopped automatically, and 7 mL of scrub medium and 5mL water were added to the scrub panels.

The dried coating films with Additive 1 were scrubbed side by side with the paint films containing no additive as the control. The paint films were scrubbed to the point of failure and the cycle numbers were recorded. The scrub test was duplicated and the results were reported as a percentage of cycle numbers of the control paint.

Blocking Resistance: The blocking resistance of the paint films was measured according to ASTM D4946. The wet paint was drawn down on a Leneta chart (WB) using a 3 mil drawdown bar, and the films were allowed to dry at room temperature for 24 hr. Two square strips measuring 2.54 x 2.54 cm were cut and placed together face to face with coating films against the films under 1000 g weight for 30 min with the load transferred to the laminate using a rubber stopper with a 2.54 cm diameter. For the elevated temperature blocking resistance test, the cut square paint films were measured in a 120°F oven under 1000 g weight for 30 min. The coating films were allowed to cool to room temperature before they were separated. The blocking resistance at room temperature and at elevated temperature was run in duplicate and reported at an average value.

Adhesion Measurement: Adhesion was measured using ASTM D3359 B. The test paint and control paint were drawn down side by side on an aged alkyd substrate with a 3 mil drawdown bar. The paint films were dried over 24 hr at room temperature and were crosshatched through to the substrate. The center of the tape was placed over the grid and smoothed into place by hand. To ensure good contact between the tape and the film, the tape was pressed firmly with the end of a pencil eraser. The tape was then removed by seizing the free end and pulling it rapidly back upon itself at as close to an angle of 180° as possible. The adhesion was rated in accordance with the classification of this method.

Stain Resistance: The stain resistance test was conducted according to ASTM D4828-94, using common household staining materials including hydrophobic and hydrophilic stains such as China marker, crayon, pencil, lipstick, ballpoint pen, mustard, coffee, wine, washable maker, and highlighter. The wet paint was applied to Leneta black charts at 7 mil and allowed to dry over seven days at room temperature. The staining materials were applied to the coating panels in sections of 2–3 cm for each stain, and were kept on the panels more than four hours. All stains were then removed using a sponge with 5 mL of a nonabrasive medium and 5 mL water. The film was allowed to dry and then rated visually for stain resistance.

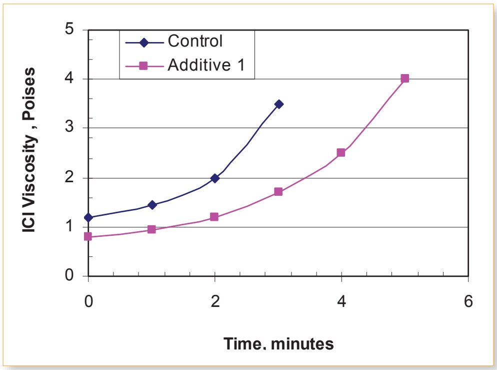

Figure 2—ICI viscosity changes as a function of time.

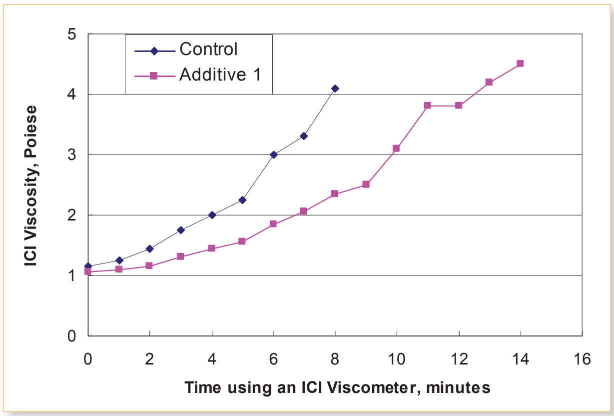

Figure 3—ICI viscosity changes as a function of time.

RESULTS AND DISCUSSION

Effects of the New Additive on Commercial Low/Zero-VOC Paints

In the simplest process, Rhodoline OTE 500 was post-added to a zero-VOC commercial latex paint with 1.0 wt%. The open time of the paint was measured according to an ASTM standard test method.[11] As shown in *Figure* 1, the open time was extended from two to eight minutes for the experimental paint.

To understand the effects of the additive on the open time of various binder systems and VOC values, different low/zero-VOC paints were obtained commercially and evaluated, and the comparison results are shown in *Table* 1. One percent of the additive was post-added to those commercial paints and the open time was measured side by side. The results indicated that the

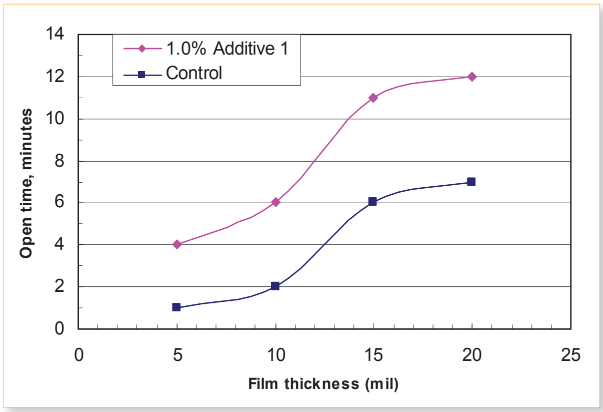

Figure 4—Relationship between open time and film thickness of zero-VOC paint.

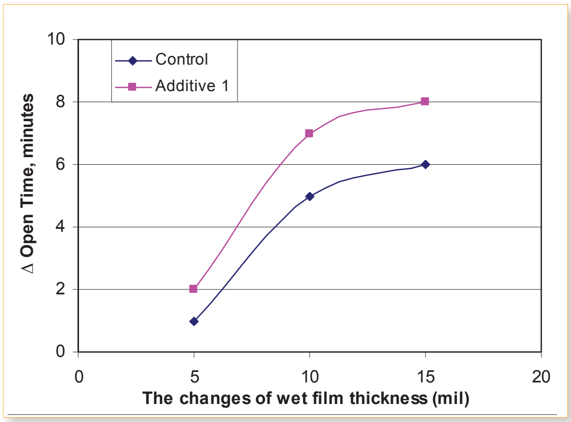

Figure 5—Changes of open time varied with coating film thickness.

common problem of the commercial low/zero-VOC paints was a short open time, in the range of zero to four minutes. The short open time prevented paint from being very well applied to substrates and hindered the ability to correct irregularities when needed. When Additive 1 was post-added to the commercial paints, the open time was prolonged by two to five times, depending on the paint formulas.

Correlation with Open Time of Aqueous Coatings

There are a number of factors that influence the open time of low/zero-VOC paints, including the binder material itself, PVC, viscosity, solvent, film thickness, and the substrate. In addition, such environmental factors as temperature, humidity, and air flow affect the open time. To eliminate external environmental factors, such as temperature and humidity, and to understand the key factors that impact the open time in the application process, the open time measurement was conducted in a room with constant temperature and humidity.

Effect of High Shear Viscosity (ICI Viscosity) on Open Time of Aqueous Coatings: The viscosity of wet paint has been recognized as one of the key factors influencing the evaporation of solvent (water). The viscosity increases significantly when almost all of the water evaporates, and the latex particles start to coalesce and form a film. Additive 1 was post-added to a commercial zero-VOC paint, and the ICI viscosity was measured as a function of time using an ICI viscometer (*Figure* 2). The results showed that the ICI viscosity of the experimental paint with Additive 1 increased slowly when compared with the control sample; i.e., it took longer to increase the ICI viscosity for the experimental paint when water evaporated from the wet paints. As is observed in *Figure* 2, ICI viscosity decreased when Additive 1 was post-added to the commercial paint. To eliminate the dilution effects on open time, Additive 1 was formulated into a low-VOC paint, and ICI viscosity was adjusted to the same value. The ICI viscosity was measured as a function of time, as shown in *Figure* 3. A similar phenomenon was observed, and the ICI viscosity of the experimental paint with Additive 1 increased slowly as compared with the control sample. It is believed that the extended open time was contributed by the additive.

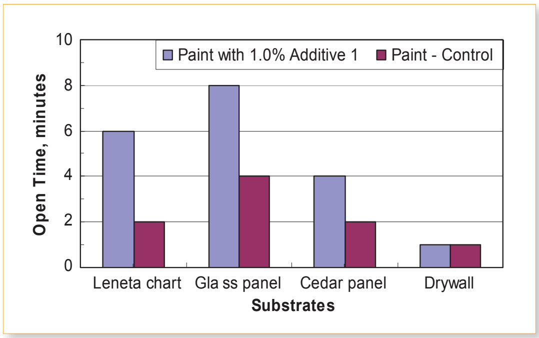

Figure 6—Effects of substrates on open time of wet paints.

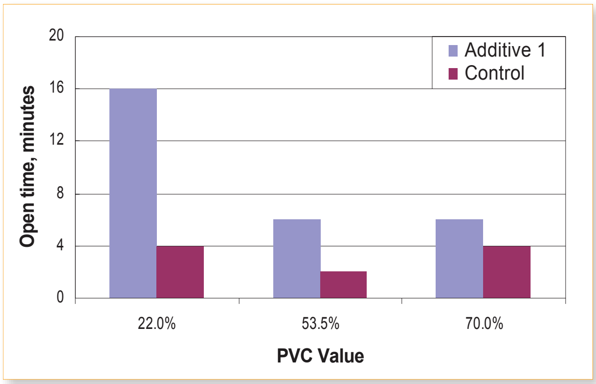

Figure 7—Impact of PVC values on open time of aqueous coatings.

Effect of Film Thickness on the Open Time of Aqueous Coatings: The open time of experimental paints with different film thicknesses (5, 10, 15, and 20 mil) was measured and compared to the control paint samples at identical conditions. The results clearly showed that the open time of the wet paint correlates with film thickness, and the open time was extended with increasing film thickness. However, the relationship to film thickenss is not linear (*Figure* 4). This occurs because water evaporation from latex polymers or wet paint starts on the top or at the edges of the thin film, and that evaporation rate is faster than that of water inside the film. This top film layer could form a barrier to decrease the evaporation rate of the free water below the top layer and keep the water inside the wet paint for a longer period of time. By plotting open time changes (ΔT) as a function of the film thickness changes of the wet paint (*Figure* 5), it is obvious that the open time changes (ΔT) in the experimental paint are greater than the changes in the control paint, and the extended open time is brought about by Additive 1.

Effect of Substrates on Open Time of Aqueous Coatings: The wet paints were applied to various substrates, e.g., a Lenata chart, glass, wood, and drywall at identical thicknesses, and the open time was measured. *Figure* 6 shows that the open time of the wet paint is substrate-dependent, and the denser and smoother surfaces have a longer open time when compared with the porous surfaces. The phenomenon of shorter open time on a porous substrate could be related to paint penetration and water evaporation in the film formation process. This can be explained by the fact that the paint penetration into a porous substrate affects the coating film thickness as compared to a nonporous substrate surface. The thinner coating film resulted in faster water evaporation.

Effect of PVC on Open Time of Aqueous Coatings: Additive 1 was incorporated into paint formulas with PVC values of 22, 53.5, and 70%. The formulas of these samples are given in *Tables* 2–4, respectively. The open time of formulated paints, with and without Additive 1, was measured side by side and open time results are shown in *Figure* 7. Obviously, the open times are related to the PVC values of the wet paints. Open time was extended by using the additive for different PVC paints, but it is more effective with low-PVC paints than in higher PVC formulations. When PVC is 22%, the open time was prolonged from 4–16 min. It is easy to understand that the higher PVC paint included more pigments or fillers in

Table 2—Paint Formula with 22% PVC

	Trial		Control	
Raw Materials	**Lb**	**Gal**	**Lb**	**Gal**
Pigment grind				
Water	80	9.60	80	9.60
Natrosol Plus 330	0.5	0.04	0.5	0.04
Rhodoline 286N	8	0.82	8	0.82
Rhodoline 643	0.4	0.06	0.5	0.07
Antarox BL-225	4	0.49	4	0.49
AMP-95	1	0.13	1	0.13
Attagel 50	5	0.25	5	0.25
Titanium dioxide, Tiona 595	230	7.00	230	7.00
Water	89.5	10.74	89.5	10.74
Subtotal	418.5	29.13	418.5	29.14
Letdown				
Acronal Optive 130	480	54.42	480	54.42
Rhodoline OTE 500	13	1.39	—	—
Rhodoline 643	2	0.28	2	0.28
Aquaflow NHS310	28	3.23	28	3.23
Water	82	9.84	95	11.40
Acrysol™ SCT-275	14	1.63	14	1.63
Polyphase 678	4	0.42	4	0.42
Total	1041.4	100.34	1041.5	100.52

Physical Properties

Total solids, %	
By weight	47.84
By volume	35.30
PVC, %	22.07
VOC, g//L	< 5.0 g/L
Weight per gal/lb	10.26
pH	8.2
Viscosity, KU	95
Viscosity, ICI	1.1

Table 3—Paint Formula with 53.5% PVC

	Trial		Control	
Raw Materials	**Lb**	**Gal**	**Lb**	**Gal**
Pigment grind				
Water	140	16.80	140	16.80
Natrosol Plus 330	0.5	0.04	0.5	0.04
AMP-95	1	0.13	1	0.13
Rhodoline 286N	8	0.82	8	0.82
Rhodoline 643	2	0.28	2	0.28
Attagel 50	5	0.25	5	0.25
Antarox BL-225	2	0.24	2	0.24
Titanium dioxide, Tiona 595	120	3.65	120	3.65
Calcium carbonate, Socal P2	100	4.43	100	4.43
Minex 10	100	4.6	100	4.6
Minex 4	50	2.3	50	2.3
Water	125	15.02	125	15.02
Letdown				
Optive 130, (50%)	250	28.34	250	28.34
Rhodoline OTE 500	6.75	0.72	0	0
Rhodoline 643	1	0.14	1	0.14
Aquaflow NHS310	20	2.31	20	2.31
Water	125	15.02	125	15.02
Acrysol SCT-275	30	3.5	23	2.68
Proxel DL	1	0.11	1	0.11
Polyphase 678	3	0.31	3	0.31
Total	1090.25	99.01	1076.5	97.47

Physical Properties

Total solids, %	
By weight	47.64
By volume	30.40
PVC, %	53.30
VOC, g//L	6.7
Weight per gal/lb	11.08
pH	9.06
Viscosity, KU	96.3
Viscosity, ICI	1.7

Table 4—Paint Formula with 70% PVC

	Trial		Control	
Raw Materials	**Lb**	**Gal**	**Lb**	**Gal**
Pigment Grind				
Water	190	22.81	190	22.81
Natrosol Plus 330	1	0.09	1	0.09
AMP-95	1	0.13	1	0.13
Rhodoline 286N	5	0.51	5	0.51
Rhodoline 643	2	0.28	2	0.28
Attagel 50	5	0.25	5	0.25
Antarox BL-225	2	0.24	2	0.24
Titanium dioxide, Tiona 595	150	4.56	150	4.56
Calcium carbonate, Socal P2	250	11.08	250	11.08
Minex 10	250	11.5	250	11.5
Minex 4	100	4.6	100	4.6
Water	75	9.0	75	9.0
Letdown				
Optive 130, (50%)	250	28.34	250	28.34
Rhodoline OTE 500	6.75	0.720	0	0
Rhodoline 643	1	0.14	1	0.14
Aquaflow NHS310	12	1.39	12	1.39
Water	95	11.4	95	11.4
Acrysol SCT-275	2.4	0.28	2.4	0.28
Proxel DL	1	0.11	1	0.11
Polyphase 678	3	0.31	3	0.31
Total	1402.2	107.74	1395.4	107.01

Physical Properties

Total solids, %	
By weight	63.6
By volume	43.0
PVC, %	70.60
VOC, g//L	2.5
Weight per gal/lb	12.52
pH	8.94
Viscosity, KU	105.0
Viscosity, ICI	1.0

Table 5—Physical Properties of a Zero-VOC Paint with Additive 1

Paint Property	**Additive 1**	**Control**
Open time, min	8	2
Viscosity, KU, equilibrium	74.8	99.4
ICI, equilibrium	0.74	0.9
Gloss, 20/60/85°, ON	34.8/71.1/94.9	22.3/62.5/93.7
Gloss, 20/60/85°, 7 days	35.4/70.8/93.2	22.6/62.9/93.6
LTC Gloss, 20/60/85°, 10 mil	34.2/70.1/94.2	22.5/63.4/93.1
Surfactant leaching	Equivalent	Control
Freeze/thaw stability, cycles	5	0
Block resistance, 3 mil, 24 h, 120°F	9	9
Scrub resistance, 7 days, %	106	100
Stain resistance	Better stain resistance to hydrophobic stains	Control

the formula, and those pigments and fillers generated porous structures in the film formation process, especially when the PVC value is greater than CPVC. The porous structures could result in many pathways for water evaporation. In the case of low-PVC paints, latex particles can pack each other and form a layer on the top or at the edge that would hinder water evaporation.

Paint Evaluation and Properties Measurements

The physical properties of the paints were also evaluated after Additive 1 was used in the formulation. The measured physical properties are given in *Table* 5. The results indicate that this additive is able to improve freeze/thaw stability from 0–5 cycles. It also increases film gloss, and helps with stain removal and scrub resistance without sacrificing other physical properties.

A Model Study of Open-Time and Film Formation of Latex Binders

Because there are so many factors that can affect the open time of aqueous coatings and latex paints, it was important to clarify the intrinsic effects of the additives. Additive 1 was formulated into a commercial latex binder with different loading levels, from 1.0–3.0 wt%. The formulated latex binders were cast onto a PET thin film on a platen of MFFT with a gradient of temperatures from 23–50°C. The PET film was removed from the platen after 10 min, soaked in a water solution, and then rinsed with water. Two portions of the cast films were observed, as shown in *Figure* 8. The latex particles of one portion redispersed into the water solution, while another portion, a clear film, was formed by a coalescence process of latex particles. The redispersed area increased with the loading level of Additive 1 and, at the same time, the film formation area decreased with the increasing amount of the additive.

It is well known that, since 1970, ethylene glycol has been used in latex paints to extend wet edge and open time.[12] An experiment was conducted by comparing effects of ethylene glycol and Additive 1. As shown in *Figure* 9, Additive 1 displayed a larger redispersed area than the area worked by ethylene glycol. The results demonstrate that this additive has a better ability to prolong the open time of the latex binder. To validate this method, a low-VOC white paint was measured using the same process, and the results are shown in *Figure* 10. It is very clear that this method can be applied to real paints for open time and wet-edge measurement. Also, Additive 1 showed a larger redispersed area than the control sample. This result agrees with the open time result measured by the ASTM method.

It is well known that the latex film formation process can be divided into three stages, as indicated in *Figure* 11.[13] In the first stage, as water evaporates from the dispersion, the concentration of latex particles increases

Figure 8—Redispersion and coalescing process of latex particles with and without Additive 1.

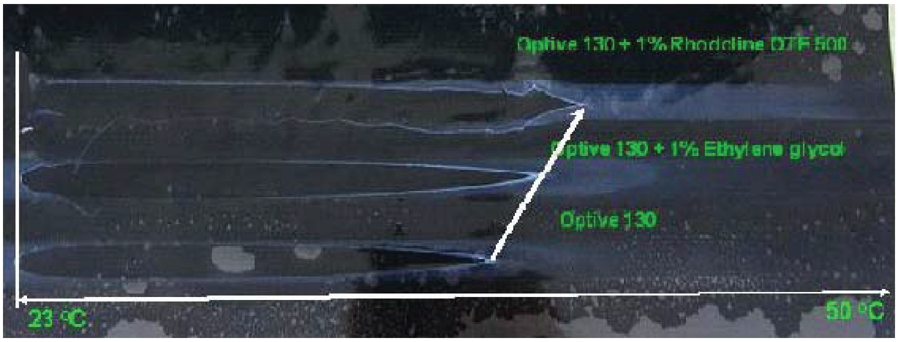

Figure 9—Redispersion and coalescing process of latex particles with Additive 1 and ethylene glycol.

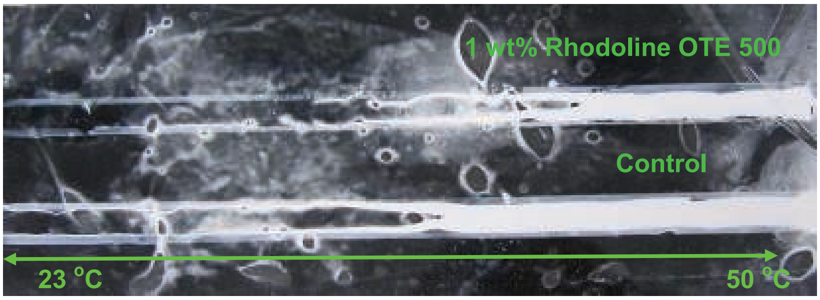

Figure 10—Redispersion and coalescing process of latex paints with and without the additive.

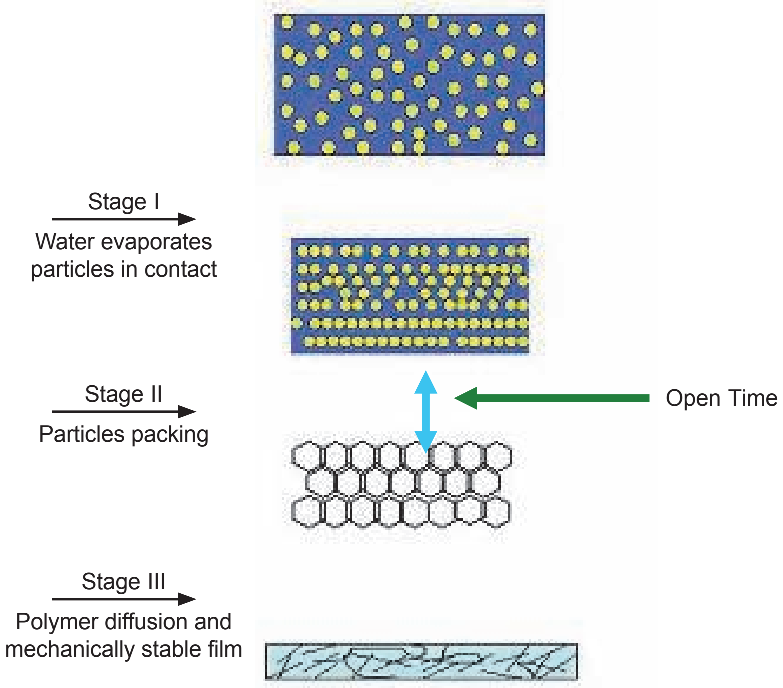

Figure 11—Film formation process of latex particles.

and the particles begin to approach each other. In the second stage, latex particles start to pack each other and particle deformation occurs. The close packing of deformed particles forms a void-free film comprised of space-filling polyhedral cells. In the final stage, the latex particles coalesce with each other and diffuse across the intercellular boundary to form entangling structures among the polymer chains. It is obvious that, before the latex particles coalesce and form a film, they can redisperse into a water solution. This means that the latex particles are in an “open” stage since their motions are in the liquid state. However, once the polymer chains become entangled and form a film, the latex particles are localized and in a “close” stage. For Additive 1, it is very likely that the additive modified the morphology of latex particles and the modified surfaces prevented the latex particles from coalescing. This process extended the open stage in the liquid state.

CONCLUSIONS

A unique additive—Rhodoline OTE 500—has been developed and successfully applied to paint formulations for various polymer binder systems to extend open time by two to five times. It is essential to balance different factors e.g., viscosity, film thickness, and substrates, to achieve a sufficient open time in the application process. The additive can be easily applied to low/zero-VOC paints either as part of the paint formulation process or as a post-formulation additive. Studies showed that Rhodoline OTE 500 offered excellent freeze/thaw stability of the zero-VOC paints from zero to five cycles. In addition to open time and freeze/thaw stability, results indicated that Rhodoline OTE 500 improved film physical properties by enhancing gloss and improving stain removal.

Further, a new method for the open time measurement of latex binders was developed to address the coalescing process and redispersion of latex particles.

References

1. Andrews, M.D., “Influence of Ethylene and Propylene Glycols on Drying Characteristics of Latex Paint,” *J. Paint Technol.,* Vol. 46, No. 598, p 40-46 (1974).
2. Sperry, P.R., et al., U.S. Patent 4,647,610.
3. Adamson, L.A., et al., U.S. Patent 5,270,380.
4. Farwaha, R., et al., U.S. Patent 5,719,244.
5. Buckmann, A.J.P., et al., U.S. Patent 7,217,758.
6. Akkerman, J., et al., European Coatings Congress, Nuremburg, Germany, March 30-April 1, 2009.
7. Overbeck, A., et al., *Prog. Org. Coat.,* Vol. 48, 125-139 (2003).
8. Meng, J., et al., “Novel Applications for Fluorosurfactants in Low-VOC Coatings,” *Paint. Coat. Ind.,* pp 84-87 (April 2007).
9. McCreight, K.W., et al., Proc. 38th Annual Waterborne Symposium, New Orleans, LA, Feb. 28-March 4, 2011.
10. Cogar, J., et al., “Novel Additives to Extend Open Time in Low-VOC Latex Paints,” *Paint. Coat. Ind.,* pp 36-38 (January 2012).
11. ASTM Standard Test Method for Open Time of Latex Paints, D7488-10.
12. Sullivan, D.A., “Water and Solvent Evaporation from Latex and Latex Paint Films,” *J. Paint Technol.,* Vol., 47, No. 610, 60-67 (1975).
13. Taylor, J.W. and Winnik, M.A., “Functional Latex and Thermoset Latex Films,” *J. Coat. Technol. Res.*, Vol. 1, No. 3, 163-190 (2004).

AUTHORS

Zhengang Zong, **Aye Min**, **Yi-Zhong Li**, **Herve Adam**, **Jean-Christophe Castaing**, and **Dayne Swearer**, Rhodia Inc., Center for Research & Technology, 350 George Patterson Blvd., Bristol, PA 19007; Zhengang.Zong@us.rhodia.com.